Double Chooz at ANL: Overview and Analysis Activities

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CLOSE DETECTOR 400 m
DISTANT DETECTOR
1 km
WEST REACTOR
EAST REACTOR
$\bar{\nu}_e$
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Double Chooz Schedule

Far Detector:

- **Far Detector commissioned and taking physics data form April 13, 2011.**
- **Remaining tasks:**

  -The lower Outer Veto (OV) installation is under way → date June10.

  -The deck installation after the lower OV system is in place → end June 24.

  -The glove box installation → end date July 1.

  -The clean tent installation → end date July 8.

  -The Z-axis deployment system installation and commissioning, radioactive source deployments in the target by mid-July.

  -The upper OV is installed after the first calibration deployments (FD complete).

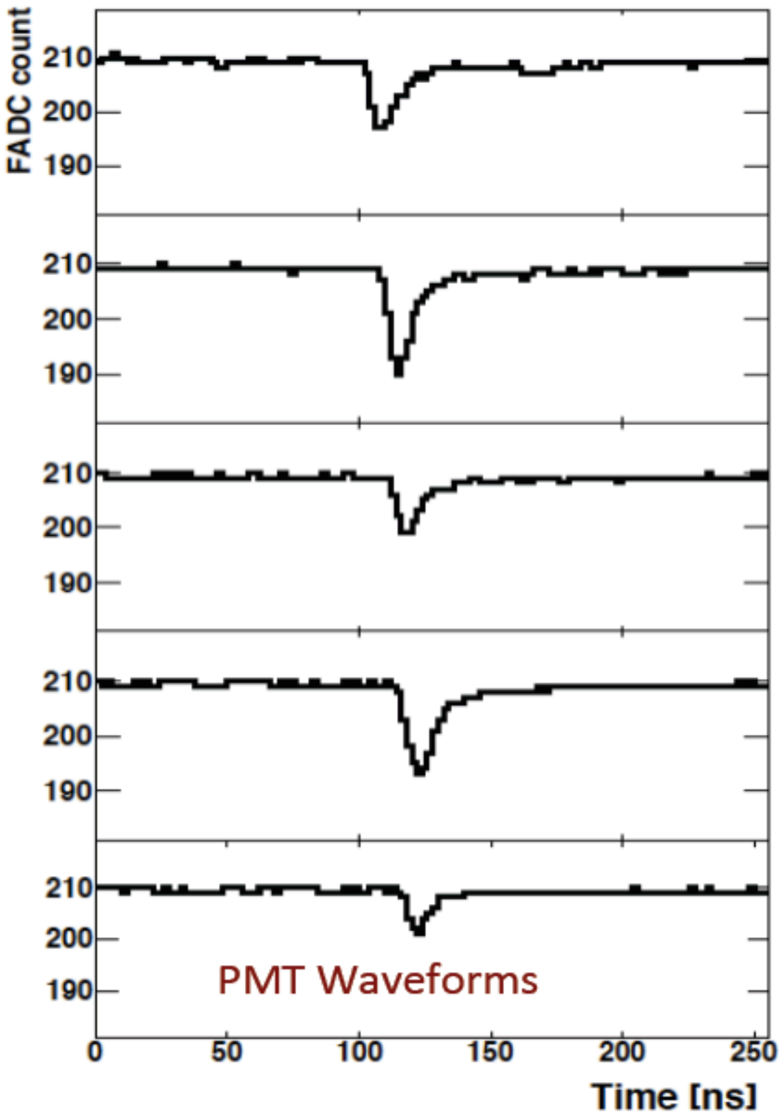
- **First Results on θ_{13}:**

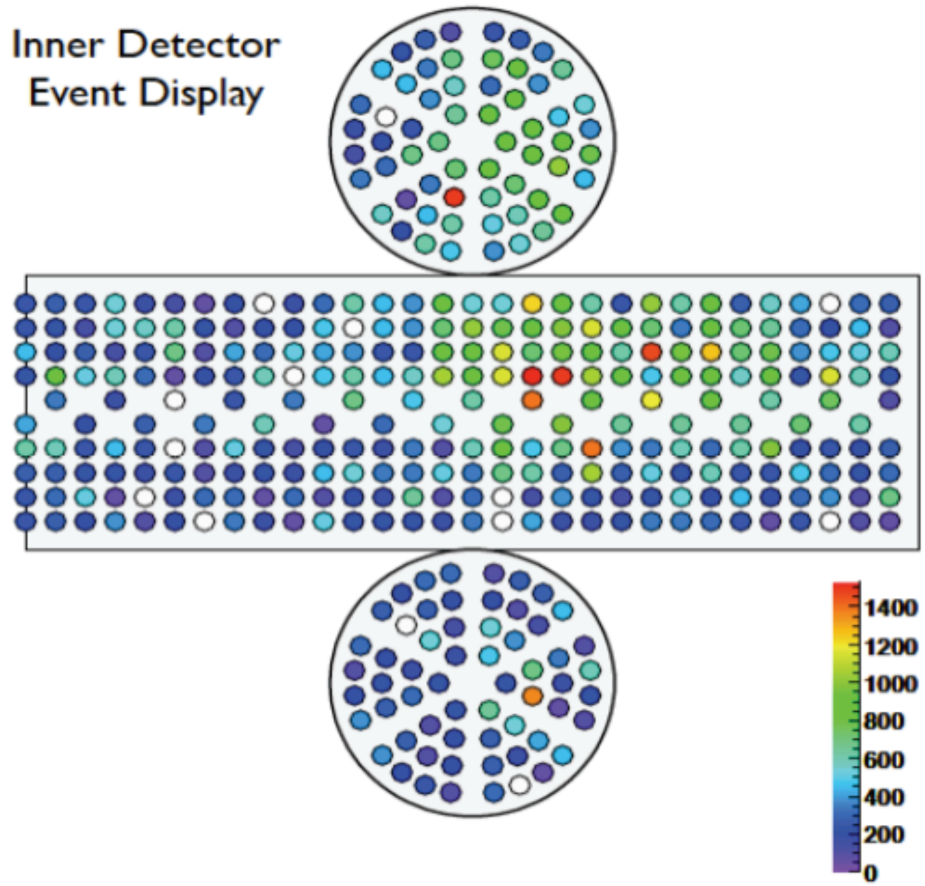
  -Expect Far Detector only result this summer when sensitivity to θ_{13} better than original CHOOZ sensitivity (~3 months of data at full reactor power).

Near Detector:

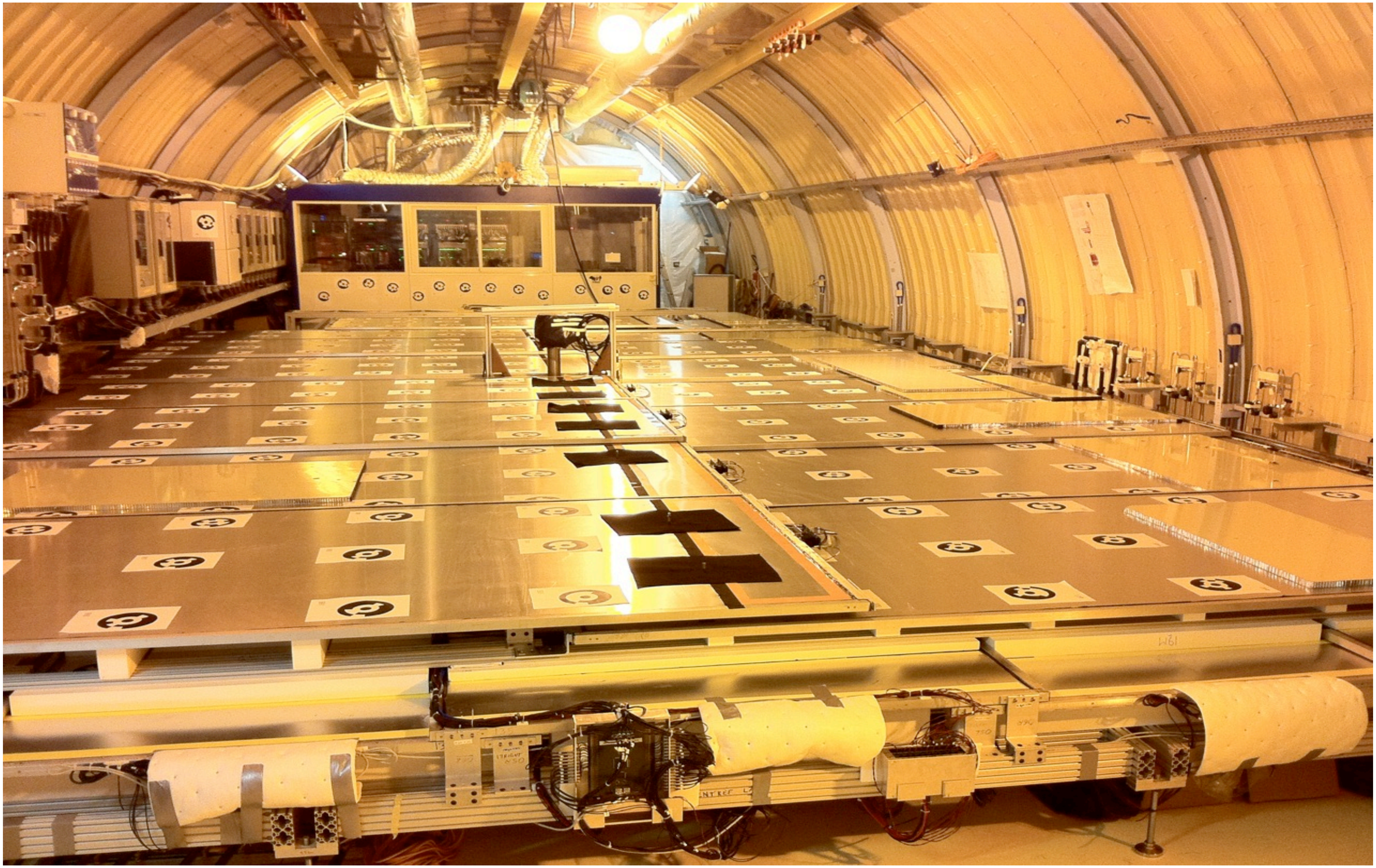
- Near Detector Lab Construction started 29th April 2011.
- The lab will be delivered in March-April 2012 ready for physics.

Example of Anti-neutrino candidate





Far Detector Lab May 2011: installation of lower outer veto



Near Site/Lab

-Construction started 29th April 2011

Double Chooz Analysis at ANL

-Short term strategy:

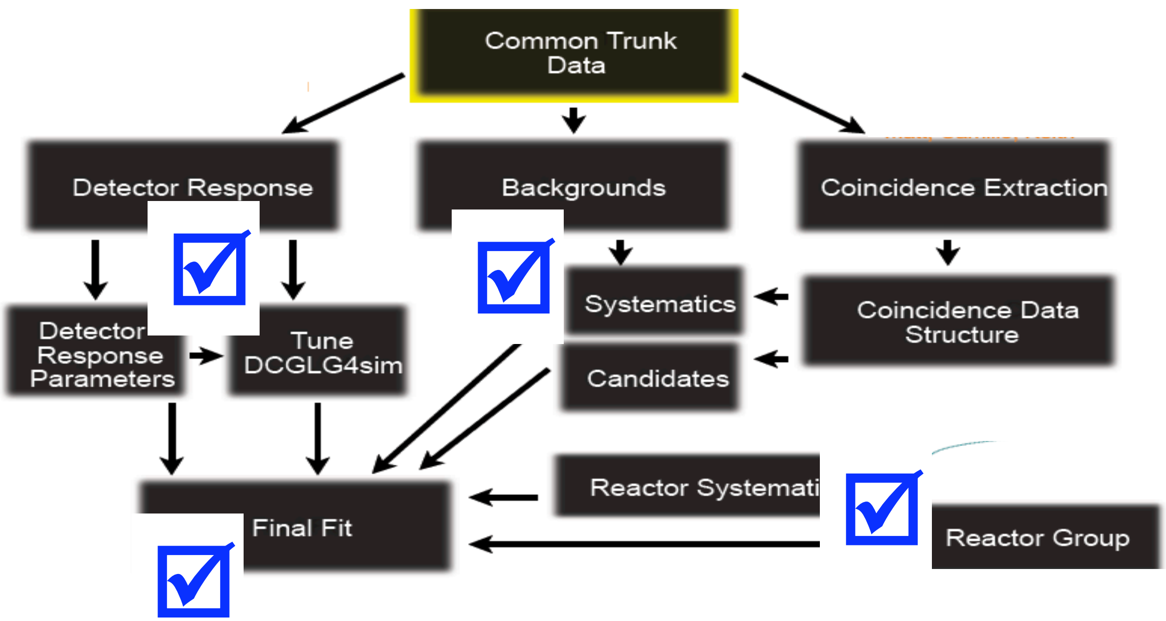
-understand detector response and determine energy scale for the first oscillation results with far detector only.

-contribute to oscillation analysis (background studies, reactor systematics, sensitivity studies).

-Longer term strategy:

-energy scale constraint from near/far detector combination.

-physics analysis and publication of cosmogenic production of neutrons, ^{9}Li, ^{12}B.

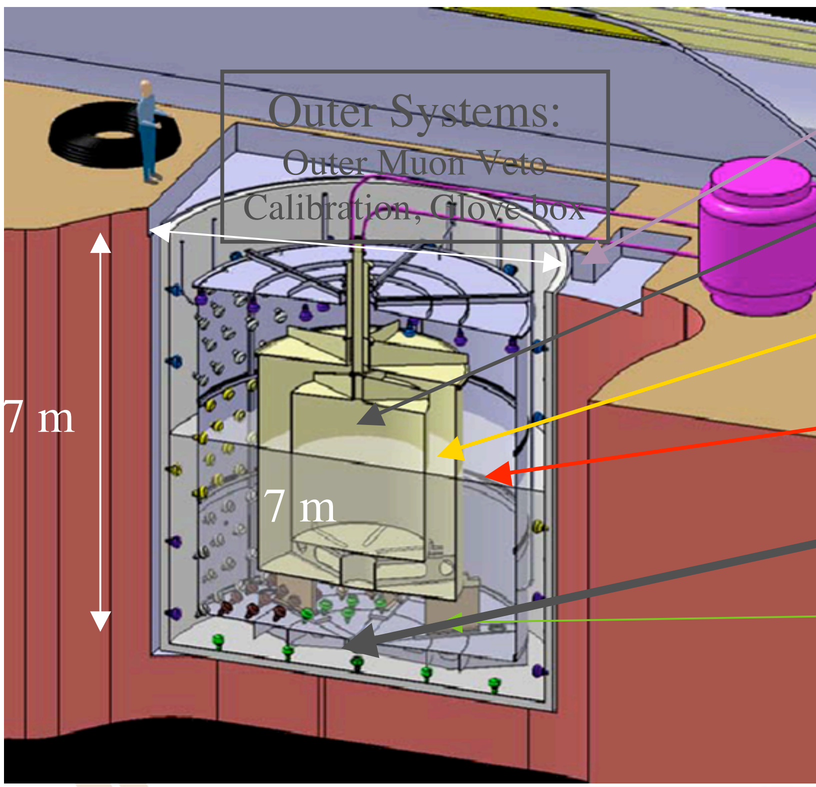


Double Chooz Analysis at ANL

-Current Analyses:

- -Michel electrons
- -Spallation neutrons
- -^{12}B Search

-Preparation for the deployment of radioactive sources and data analysis.



Shielding steel and external vessel

Target- Gd loaded scintillatopr

Gamma catcher: scintillator with no Gd

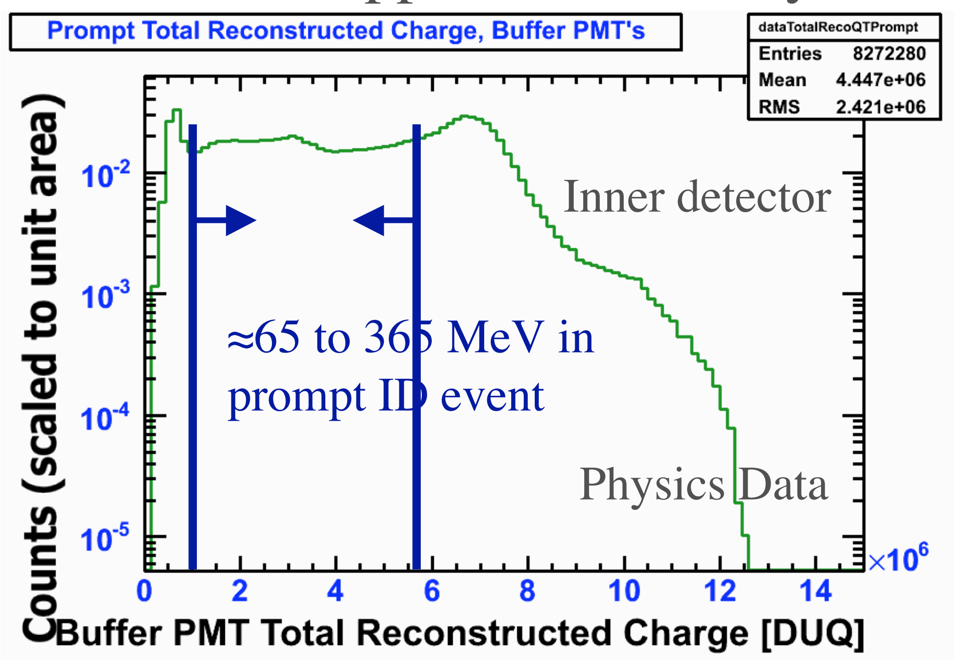
BUFFER Mineral Oil with no scintillator

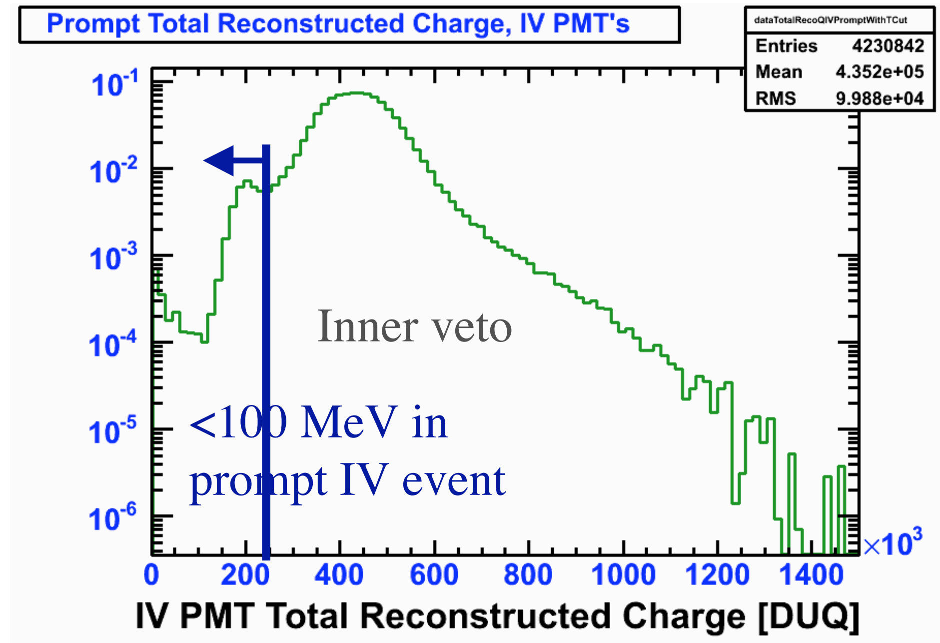
Optically separated inner veto to tag muons

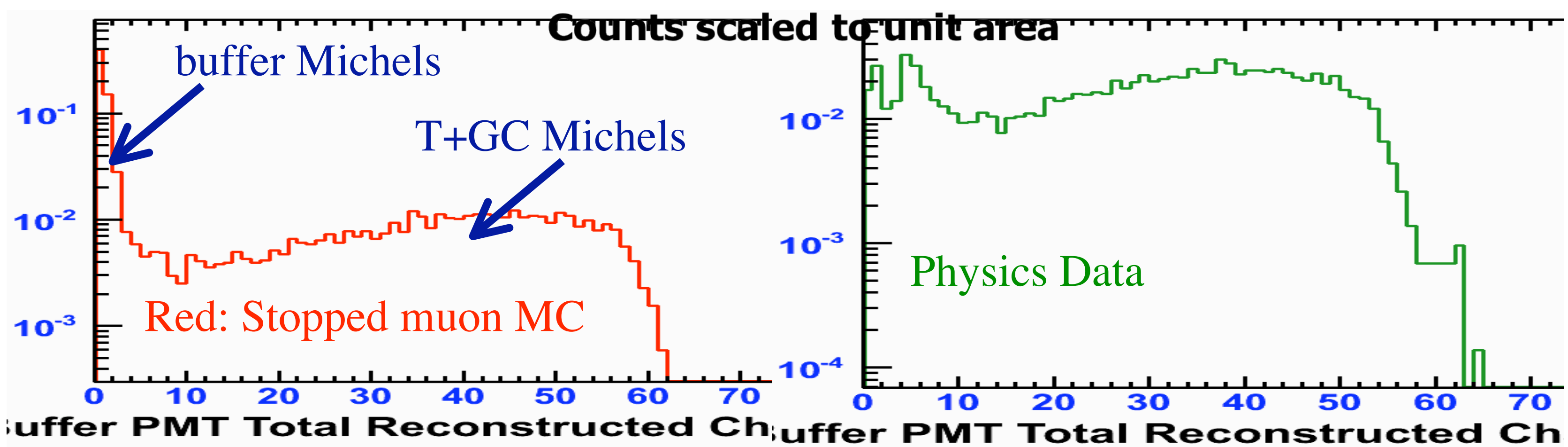
Modular Frame to support photomultipliers

Michel Electrons

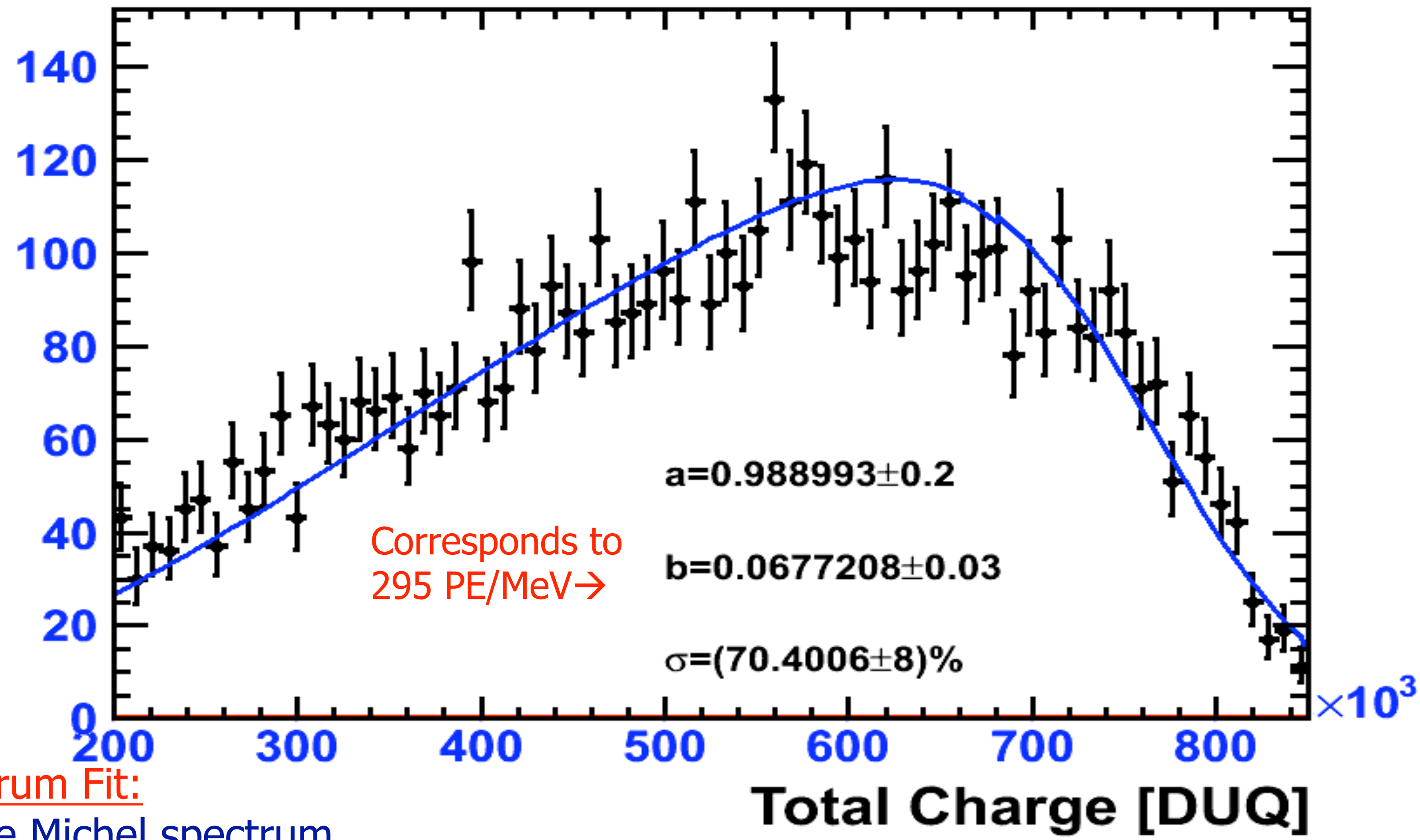
-look for stopped muon decay into e⁻







Michel Electron Spectrum From 1 Day of Data



Spectrum Fit:

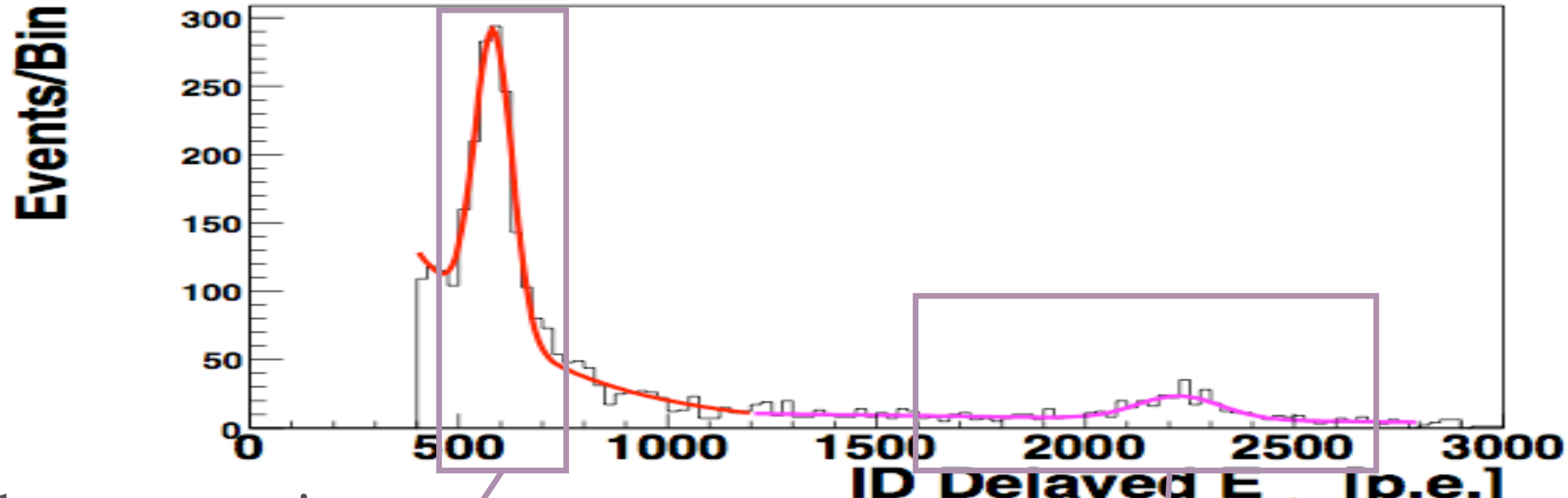
1)True Michel spectrum

2)$E=a+bQ_{tot}$

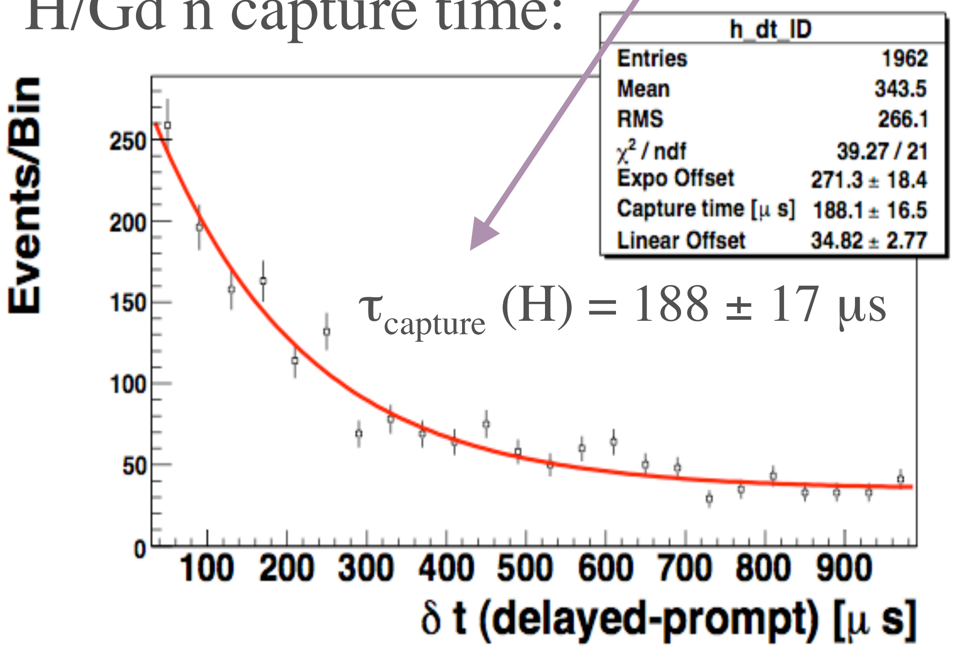
3)Convolved with gaussian energy resolution $E_{res}=\sigma\sqrt{E}$

Spallation neutrons

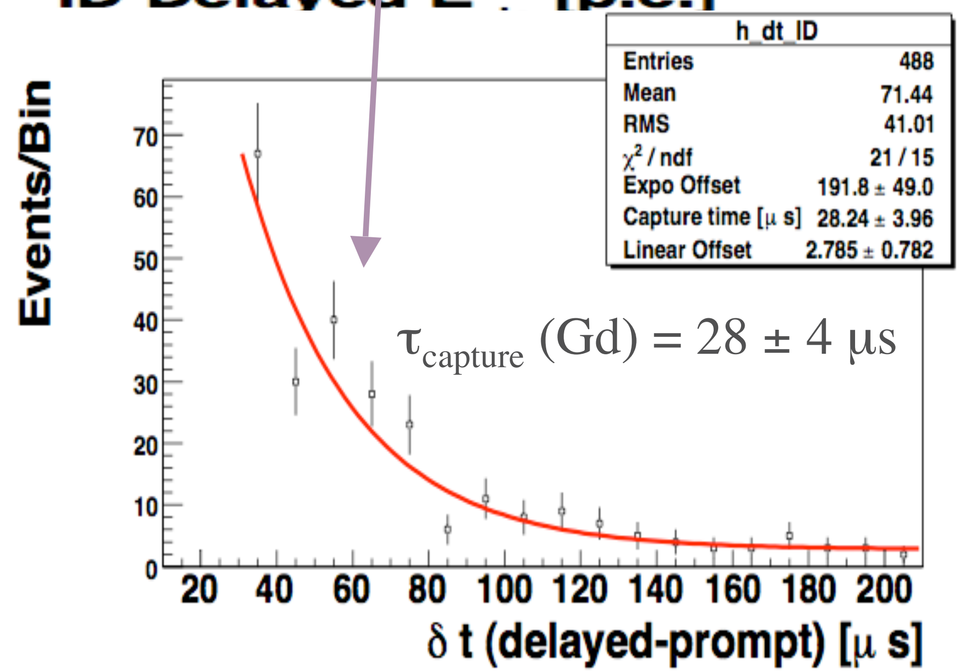
-look for n produced by muon spallation, captured at H or Gd:



H/Gd n capture time:

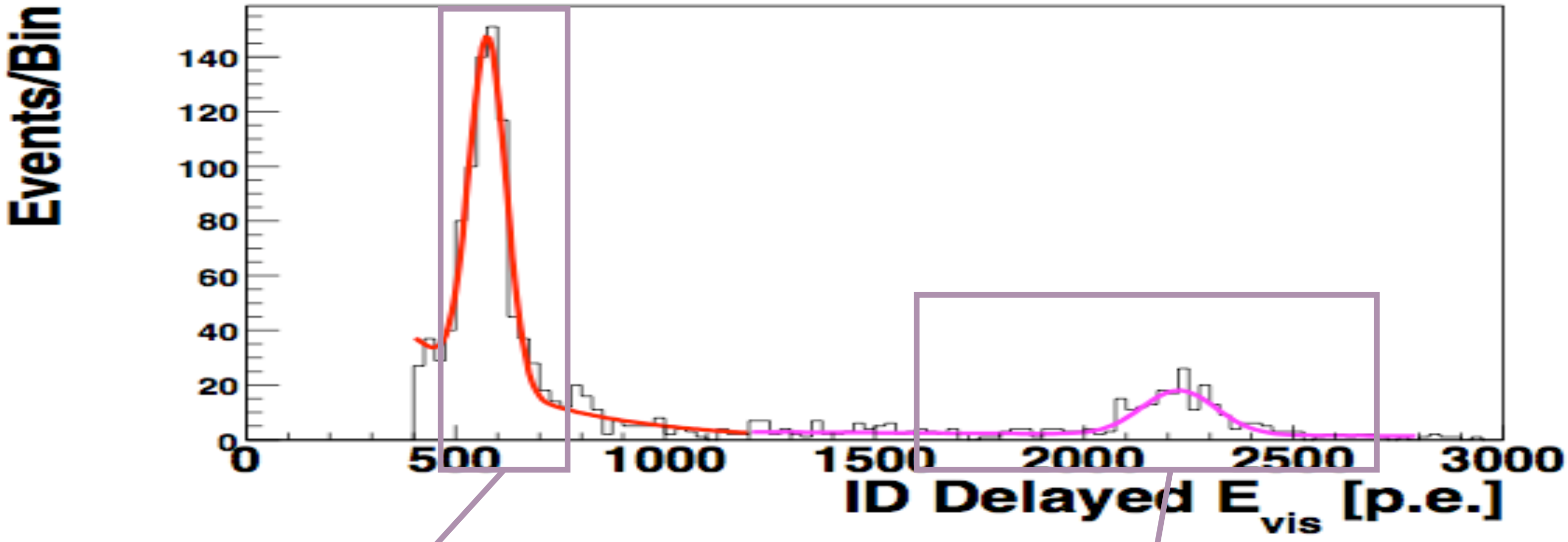


$\tau_{capture}$ (H) = 188 ± 17 μs



$\tau_{capture}$ (Gd) = 28 ± 4 μs

Energy scale and resolution:



1 Area 554.3 ± 33.0
2 Mean 5.76296e+02 ± 2.48679e+00
3 Sigma 4.36259e+01 ± 2.60420e+00

1 Area 143.8 ± 14.4
2 Mean 2.22658e+03 ± 9.15200e+00
3 Sigma 8.88500e+01 ± 9.09555e+00

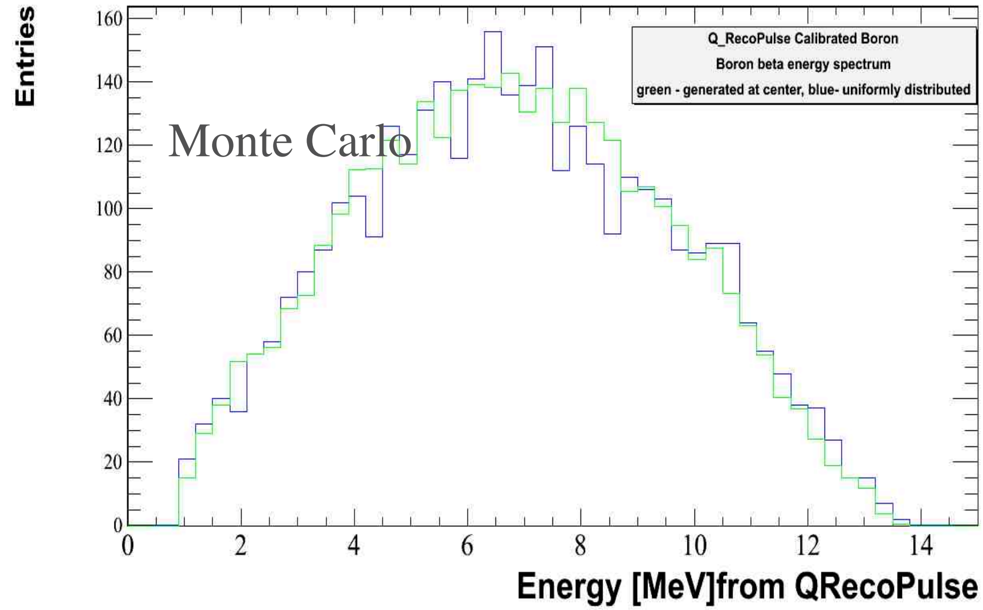
Assume: E_γ (nH) = 2.2 MeV, E_γ (nGd) = 8.0 MeV.

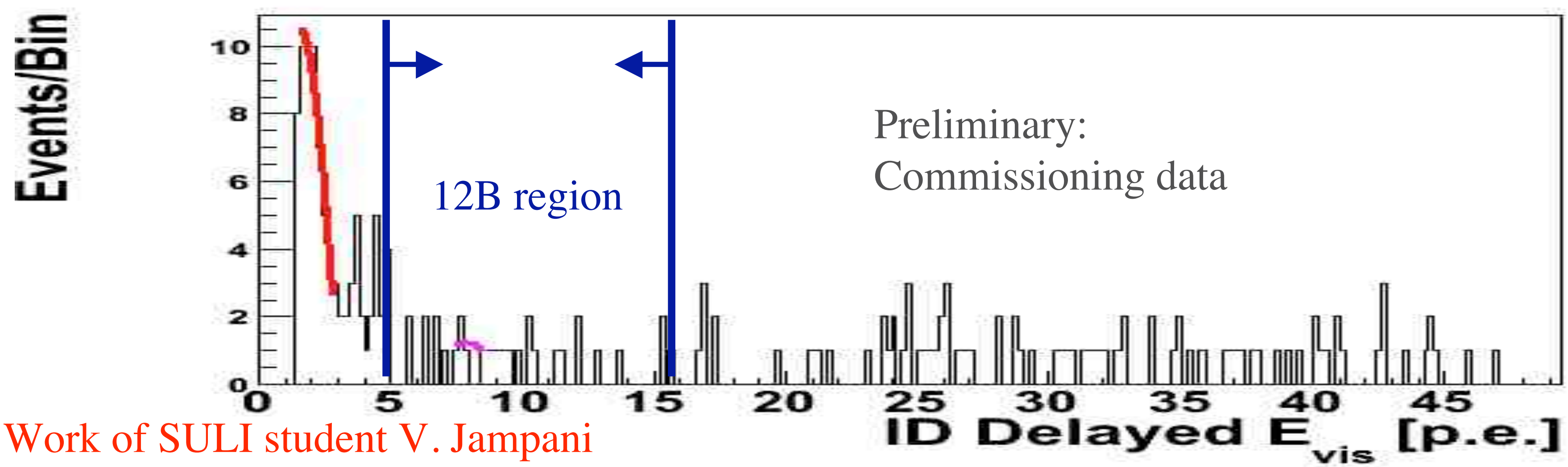
⟹ If linear scale: $E[\mathrm{MeV}] = 0.00351\, N_{pe} + 0.175$, or $\Delta N_{pe}/\Delta E \approx 285$ pe/MeV.

Energy resolution: $\sigma/E = 7.6\%$ @ 2.2 MeV, 4.0% @ 8.0 MeV.

^{12}B Search

-Boron 12: Produced in a relatively high amount by cosmic muons (Kamland, MC simulations)
-A relatively long lived radio isotope which undergoes beta decay with $T_{1/2} = 20.2$ ms
-Understand detector response: use in the energy calibration
-Determine cross section for Boron production in the long run
-Possibility of mimicking IBD signal together with uncorrelated spallation neutrons will be examined





Work of SULI student V. Jampani

Note on Cosmogenic Source Calibration

-Use of cosmogenic sources is viewed as a complementary tool to the calibration sources.

-Advantage: uniform distribution of spallation products, i.e. spallation neutrons, mimicking the uniformity of IBD events.

-Disadvantage: -vertex of interaction is not precisely known
-cannot be used to tune the vertex fitter
-cannot study the energy scale dependence on the position.

-The spallation neutrons (and other events) used to monitor the stability of the detector and interpolate the detector response between source calibrations.

-Monitoring is also useful for checking that source deployments do not adversely affect detector stability.

Preparation for the first source calibration

-Our current analysis involvement serves as a preparation for the analysis of the radioactive source data

-The list of radioactive sources available for the first deployment:

- -68Ge (annihilation radiation)
- -untagged 252Cf (neutrons)
- -137Cs (0.662 MeV radiation)
- -60Co (1.173 + 1.332 MeV radiation)

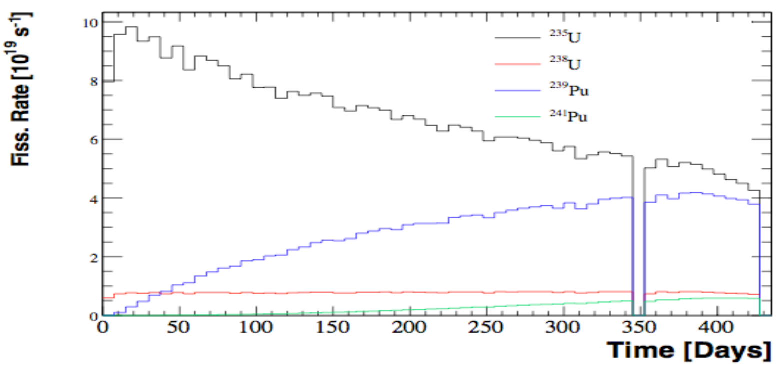
-The source activities are in a range of several 10s of Bq.
-A 10000 event statistics per source position in 5-20 minute periods per source
-Deploying and retrieving the Z-axis system would take just under one hour.
-In practice deploy all four calibration sources (68Ge, 252Cf, 137Cs and 60Co) in 5-10 locations along the Z-axis in an eight hour sequence.

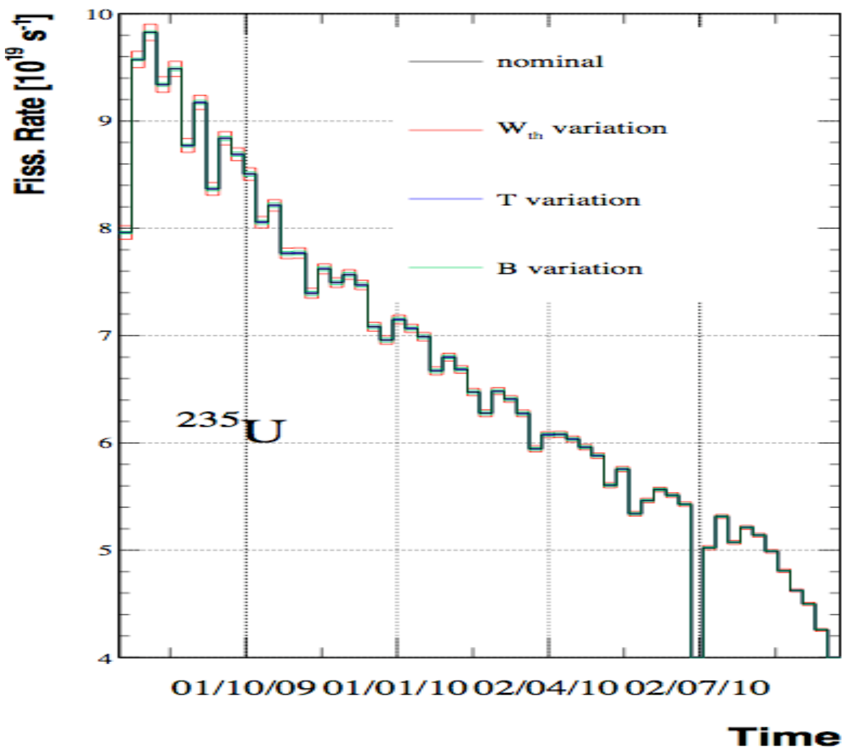
-The initial calibration:
-Facilitate software development (reconstruction, high level analysis, detector simulation).
-Define what further calibrations should be carried out for the first paper.

Reactor Flux Calculation and Systematics

-Use DRAGON (US) and MURE (France) simulation codes to predict anti-neutrino flux at Double Chooz detectors

-Calculate systematic uncertainty in the flux prediction.





-Paper drafted:

Simulation of Reactors for Anti-neutrino Experments Using DRAGON and MURE

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Abstract

Rising interest in reactor-based antineutrino experiments motivates new, fast, and accessible simulations to predict reactor fission rates. Here we present results from the DRAGON simulation code and the MURE Monte Carlo and compare them to other industry standards for reactor modeling. We use the published data from the Takahama reactor to document the quality of the simulations. The propagation of the uncertainty in the reactor parameters to predictions of antineutrino flux is also discussed.

Keywords: Neutrinos Reactors DRAGON MURE

As new high-power reactors come on-line, opportunities for reactor-based anti-neutrino experiments are on the rise. Three new experiments searching for the final neutrino oscillation pa-

formation is fed to code such as DRAGON and MURE, which simulate the time-evolution of the fissile materials in the core. Then, in a second step, the fission rate for each isotope is con-

Covariance matrix is: $M_{ij} = \rho_{ij}\, \sigma_i\, \sigma_j$ (i= ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu).

3.56434e-05	3.72435e-05	6.15896e-05	0.000110724
3.72435e-05	0.000109136	0.000122831	0.000207399
6.15896e-05	0.000122831	0.000157767	0.000275017
0.000110724	0.000207399	0.000275017	0.000483988

Summary

-Far Detector commissioned and taking physics data form April 13, 2011.
-ANL grpup actively involved in data analysis.
-Expect the Z-axis deployment system installation and commissioning, radioactive source deployments in the target by mid-July.
-Preparation for the deployment of radioactive sources and data analysis is current effort at ANL.
-Expect Far Detector only result this year when sensitivity to θ_{13} better than original CHOOZ sensitivity (~3 months of data at full reactor power).

Backups

Issues to address in the initial calibration

In this initial calibration phase one needs to look for issues related to:

-the FEE response efficiency,
-effects of possible non-linearities in the energy scale,
-understanding of the energy resolution,
-the variation of detector response with position,
-derivation of first precise energy scale,
-expected performance of the data analysis software,
-possible instabilities of scintillator,
-appearance of Gd-loaded liquid scintillator leak from neutrino target to gamma-catcher region,
-detector simulation, and
-biases in the reconstruction algorithms.
-(there may be other issues to add to this list).

Expected specific results from the initial calibration

-The total charge distribution for each deployment position.

-Charge distribution for each deployment position for each PMT.

-Time distribution for each deployment position for each PMT.

-Event yields for each deployment position. In the case of 252Cf events, there would typically be multiple neutron capture candidates per sequential event.

-Derive the time offsets and gains with the radioactive calibration sources deployed along the Z-axis.

-Detector simulation of source deployments to obtain the corresponding MC distributions and yields.

-By comparing MC to data one could explore a number of MC issues: is the Cherenkov treatment in the MC is sufficient, if the characterization of the PE reconstruction non-linearity is complete, etc.